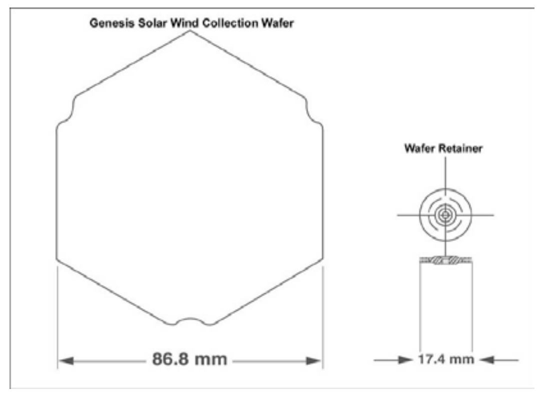
Data Analysis and Generalizations

Solar Wind Catcher

STUDENT TEXT

The Genesis spacecraft was launched on August 8, 2001, on a mission to “catch a piece of the Sun.” The spacecraft traveled about one million miles toward the Sun to a place called L1 to Sunbathe (collect solar wind) for 2.5 years. The collected solar wind will be analyzed to determine the isotopic abundances of the solar wind in order to understand the makeup of the original solar nebula and to compare this information with what is known about the planets. The Genesis spacecraft collects solar wind through a system of passive collector wafers and a new instrument called the concentrator. In this text, you will read brief descriptions about the collection wafers, array frames, concentrator, and electron and ion monitors. To learn more about solar wind collection, see “*Dynamic Design: A Collection Process*.” To learn more about wafer assembly, see “*Dynamic Design: The Cleanroom*.”

Solar Wind Collectors
One way solar wind is captured by the Genesis spacecraft is through a series of collection wafers. The wafers are mounted on five collector arrays that are 73 cm in diameter on the Genesis payload. Each array consists of 42 complete hexagon wafers and 13 incomplete hexagon wafers. The wafers are placed on the array so that there is one centimeter of space between them. There are four arrays stacked together in the container and one found on the lid. The lower stacked arrays are shaded from the solar wind when not in use. The top array and the array in the lid are used to collect bulk solar wind (they will always be exposed). The bottom three arrays are used to collect samples from specific regimes of solar wind. The solar wind collectors are constructed from wafers made of very pure, very clean materials attached to an array frame. Most of the wafers are hexagon-shaped, though some are halfhexagons, near the edge of the array. Hexagon-shaped wafers maximize the collection area by nesting close to one another in the array. Most of the wafers are made from silicon, and others are diamond, platinum, and germanium. Some wafers are layered with aluminum and gold. The science team chose these materials as collectors because each has advantages during analysis. The wafers will capture and hold the solar wind samples. During the two year “Sun bath,” every element from hydrogen to uranium will be implanted. All wafer materials that are exposed to the solar wind will collect all solar wind elements.



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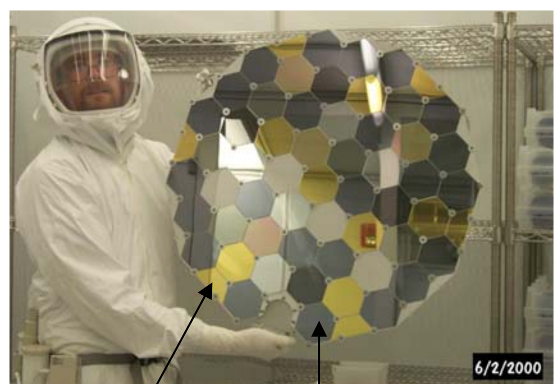

Johnson Space Center

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Back on Earth, the silicon wafers, which are between 0.4 and 0.6 mm thick, will be used to analyze most of the elements and isotopes. Chemical vapor deposited diamond will be used to analyze oxygen, nitrogen, and other light elements. Aluminum will be used for the noble gases. Diamond, gold/platinum, germanium, and other substances will be used for the alkali and radioactive elements.

Instruments
According to Los Alamos National Laboratory (LANL) Genesis Lead Roger Wiens, “Los Alamos is responsible for three of the instruments on the Genesis mission. In fact, we are responsible for the three electrostatic instruments that interact with the solar wind actively. Those three instruments are the ion spectrometer, the electron spectrometer (sometimes called the monitors, because they are checking in real time the solar wind) and then

also the solar wind concentrator, which is a brand new kind of instrument. In addition to those instruments, we are responsible for the science algorithm, the robotic logic that the spacecraft has, which takes the raw data from the solar wind as measured by the monitors, and it reduces that, tries to understand what regime of the solar wind or what type of solar wind is blowing, and then commands the proper array to be deployed to collect that type of solar wind. The logic also controls the voltages on the concentrator so that it can give an optimal concentration of solar wind onto its target."

The Concentrator

The job of the concentrator is to repel hydrogen (protons) and to enhance the density of heavy ions (particularly oxygen) that will be collected. The concentrator is made up of several grids, which are like thin window screens, a solid electrode, and the target material. The grids act like lenses for the ions that pass through them because of the electric field around them when they are held at a high voltage.

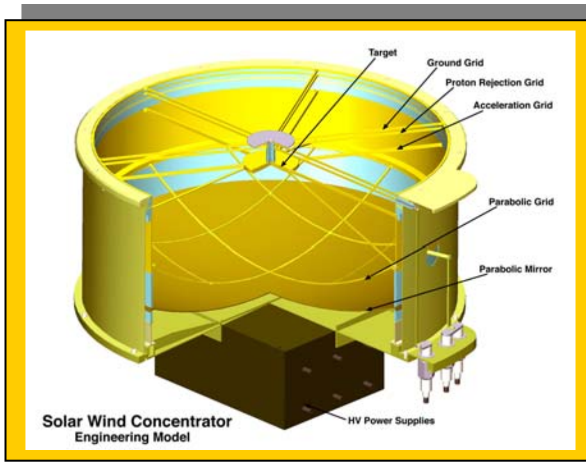

Diagram of Genesis Ion Concentrator

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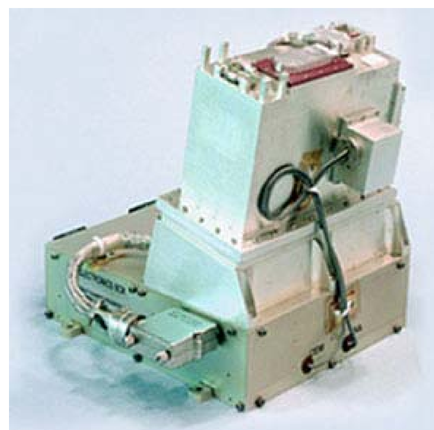
The top grid is a grounded grid, which keeps electric fields from the interior grids from leaking out into space. Below that is a proton rejection grid. (How would you design a grid that would repel protons but allow heavier, more energetic ions to enter? Why would the Genesis scientists want to repel protons? HINT: What is the largest component of solar wind?)

The third grid is an acceleration grid. By holding this grid at a negative high voltage, ions are accelerated towards it, and their trajectories are straightened out in the process. When ions pass through this grid, they are better aligned with the mirror, so they can be focused on the target better. These three top grids are flat. The fourth grid is curved, and roughly parabolic in shape. It is at the same voltage as the acceleration grid. Below this grid is the solid electrode, which repels and reflects the ions back toward the target. The electrode surface consists of a series of micro-steps that reflect photons out of the concentrator so that the Sun's light does not hit the target.

The target is made of manufactured diamond that was specially designed for the Genesis mission. Concentrator models were tested in Switzerland and at the Los Alamos National Laboratory. In addition, computer models were used to simulate the instrument's performance. One such computer model simulated 50 million ion trajectories to make sure the instrument had the proper focal length. The concentrator will provide a much higher concentration sample of solar wind oxygen, an element scientists think will be important in understanding how the Earth and planets were formed. How does this new technology and design enable scientists to study the solar wind in ways that have never been done before?



Genesis Ion Monitor (GIM)

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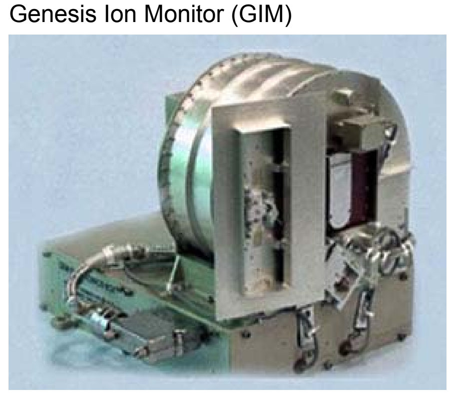

Genesis Electron Monitor (GEM)

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The Monitors

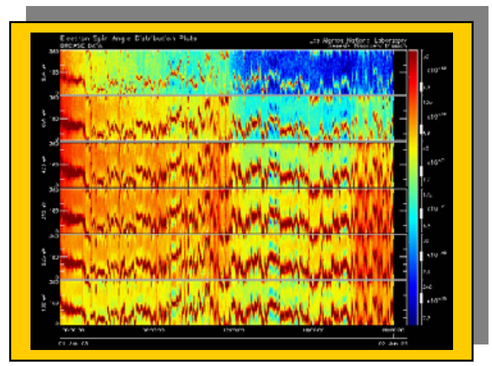
There are monitors onboard Genesis that serve as the eyes and ears of the spacecraft. The Genesis Ion Monitor (GIM) detects the speed of ions coming from the solar wind. The Genesis Electron Monitor (GEM) detects the direction from which the solar wind electrons are coming. Each monitor has a small door that opens to let particles in. Electrostatic analyzers then allow particles with a certain amount of energy to interact with the detectors. According to LANL Monitors Development Leader Bruce Barraclough, "The analyzer acts as a filter, allowing different energy particles to come in. They interact with the detectors and we count how many came in in that brief time, and we know how many of what energy, from what angle the particles will have come in from. Using that information we can build up a three dimensional picture of the particle distributions, and energies, and directions they are coming from in space." The data from the eyes and the ears, the GIM and GEM, are fed to computers. These computers act like the brain, and make a decision about which hand to extend, in the form of an array frame. This process optimizes the collection of solar wind.

From Spacecraft to Earth

The solar wind data are also sent back to Earth so scientists at the Los Alamos National Laboratory can have access to current information about solar wind that has interacted with the Genesis spacecraft.

Genesis data comes via the Deep Space Network (DSN). According to NASA Engineer Marla Thornton, the Jet Propulsion Laboratory (JPL), "Genesis downlinks the science data when directed by the background sequence. The background sequence is an onboard set of commands that handles the DSN contacts and the spacecraft telecommunications among other things. The data received at the DSN antenna goes through the microwave system, receivers, through ground communications to JPL. At JPL, the data goes through frame synchronization and packet extraction and the data is put onto the Flight data database. There is a process run against the database to pull off the science data and to place that data on a server that LANL can access."

Roger Wiens adds, "The data are broadcast down from the spacecraft two or usually three times a week, several hours at a time. Each morning one of our servers here runs a "chron" (regularly scheduled) job that looks for new data, and if available, plots the new data as gif files that are stored where the Web browser can access it. Genesis is unique in that we process the moments (speed, density, temperature, alpha-proton ratio) and bi-directional electron (BDE) indicator on board (the spacecraft). So a significant step includes onboard processing of the raw data from the monitors to yield the moments. What we have plotted on the Web for the ions and BDEs are the results of the on-board calculations." In the next activity you will begin observing and asking questions about actual solar wind data provided to scientists from the Genesis spacecraft.



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Electron Spin Angle Distribution Plots, June 1, 2003